VARIABLE FREQUENCY DRIVE SPECIFICATION

Carlos B. Montoya
CESPK-ED-M
(916) 557-7228

INTRODUCTION

Most new designs for mechanical fans and pumps use Variable Frequency Drive (VFD) motor controllers to achieve better energy efficiency. The current guide specification for Electrical Work, Interior, CEGS-16415, does not address this equipment. This paper provides a sample specification for VFD's which may be inserted into paragraph 3.14, Motor Control, of CEGS-16415. The specification is based on input from three major manufacturers: ABB, Allen-Bradley, and Square D.

SUGGESTED SPECIFICATION

3.14.1 Variable Frequency Drive

3.14.1.1 Scope of work

This section provides specification requirements for variable frequency drives (VF Drives) for use with NEMA B [NEMA D, NEMA A, _____, Synchronous] design AC squirrel cage induction motors. The Contractor shall provide the following: a) provide the Contracting officer with the VF Drive manufacturer's written concurrence that the output of the Drive is compatible with the design and construction of the associated motor to be supplied by the Drive; b) a VF Drive manufacturer's representative to field test, adjust and certify all installed VF Drives for satisfactory operation with motor load running under all design conditions.

3.14.1.2 Warranty

Provide a 3-year parts warranty, on materials and workmanship, and 1-year labor warranty from the date of field certification by manufacturer's representative of satisfactory operation. The manufacturer's turn around period to repair or replace the VF Drive shall be no more than 48 hours.

3.14.1.3 Quality Assurance

The manufacturer of the VF Drive shall be a certified ISO 9001

facility. The VF Drive and all associated optional equipment shall be UL listed according to Power Conversion Equipment UL 508C. A UL label shall be attached inside each enclosure as verification. Every Power Converter (a component of the VF Drive) shall be tested with an actual AC Induction Motor 100% loaded and temperature cycled to the full range of the VF Drive. All VF Drive door mounted pilot devices shall be tested to verify successful operation. The VF Drive shall be submitted to a HI-Pot test with all enclosed devices mounted and wired, prior to shipment. Documentation shall be furnished to verify successful completion of all the above, upon request of the Contracting Officer.

3.14.1.4 General Description

Alternate control techniques other than pulse width modulated (PWM) are not acceptable. The VF Drive shall convert the input AC mains power to an adjustable frequency and voltage as defined in the following sub-paragraphs. The input power section shall utilize a full wave bridge design incorporating diode rectifiers (SCR’s may be incorporated at 40 horsepower and above). The diode rectifiers shall convert fixed voltage and frequency, AC line power to fixed DC voltage. This power section shall be insensitive to phase rotation of the AC line. The DC bus shall have external connections for standby battery back-up or for linking multiple VF Drives with DC buses for management of regeneration power. The output power section shall change fixed DC voltage to adjustable frequency AC voltage. This section shall utilize Insulated Gate Bipolar Transistors (IGBTs) or Intelligent Power Modules (IPMs) as required by the current rating of the motor.

3.14.1.5 Construction

A. The VF Drive shall be mounted in a NEMA 1 [NEMA 12] enclosure with [without] an external operated disconnect device. A mechanical interlock shall prevent an operator from opening the VF Drive door when the disconnect is in the on position. Another mechanical interlock shall prevent an operator from placing the disconnect in the on position while the VF Drive door is open. It shall be possible for authorized personnel to defeat these interlocks.

B. Provisions shall be provided for locking all disconnects in the off position with up to three padlocks.

C. Current limiting fuses shall be installed and wired to the AC Drive input.

D. Provisions shall be made for accepting a padlock to lock the VF Drive enclosure door.

3.14.1.6 Motor Data

****
The VF Drive should always be sized per the motor's maximum current requirements under breakaway torque demands, since the maximum demands placed on the motor by its connected load also must be met by the VF Drive. To control more than one motor from a VF Drive, calculate the total peak currents of all motor loads under the worst operating conditions. Then size the Drive based on this maximum current requirement. When a VF Drive is used, the motor speed is reduced (intentionally) and more heat is generated in the motor, with less capability to dissipate the heat. Therefore, to provide additional thermal capacity to the motor add the following sentence to the MOTORS paragraph: "Motors connected to VF Drives shall have a 1.15 service factor, but the connected load shall be sized to not exceed the 1.0 service factor of the motor. Provide motor winding thermal sensing thermistors (PTC) in motors to be connected to VF Drives."
****

The contractor shall ultimately be responsible for obtaining all necessary motor(s) technical data from the motor or equipment manufacturer, to properly size the VF Drive. The VF Drive shall be sized per the motor's maximum current requirements under breakaway torque demands, not per the motor horsepower rating. Size the Drive to operate the AC motor(s) of the following equipment:

1. Equipment Name: [_____], shown on Mechanical and Electrical drawings.
Motor Horsepower: [____], or as provided by the manufacturer
Motor maximum current at breakaway torque: [___Amps], unless otherwise indicated by manufacturer.
Motor full load amperes: [____Amps], or as provided by the manufacturer.
Motor RPM: 1800 @ 60Hz, unless otherwise indicated.
Motor voltage: 460V [____]
Motor service factor: 1.15

[2. Equipment Name: [_____], shown on Mechanical and Electrical drawings.
Motor Horsepower: as provided by the manufacturer.
Motor maximum current at breakaway torque: [___Amps], unless otherwise indicated by manufacturer.
Motor full load amperes: [____Amps], or as provided by the

manufacturer.
Motor RPM: 1800 @ 60Hz, unless otherwise indicated.
Motor voltage: 460V [____]
Motor service factor: 1.15

3.14.1.7 Application Data

****
Variable Torque motors are used to operate fans and centrifugal pumps; Constant Torque motors are used on conveyors, positive displacement pumps, and compressors; Constant horsepower motors are used on machine tools and winches.
****

The VF Drive shall be sized to operate a [Variable Torque, Variable Torque Low Noise, Constant Torque, Constant Horsepower, Impact] load. The speed range shall be from a minimum speed of 0.5 Hertz to a maximum speed of 400 Hertz.

3.14.1.8 Environmental Ratings

A. The VF Drive shall be of construction that allows operation in a pollution Degree 2 environment, minimum.

B. The VF Drive shall be designed to operate in an ambient temperature from 0 to + 40 degrees C (+32 to 104 degrees F).

C. The storage temperature range shall be -25 to +70 degrees C (-13 to 158 degrees F). The maximum relative humidity shall be 95% at 40 degrees C, non-condensing.

D. The VF Drive shall be rated to operate at altitudes less than or equal to 3,300 ft(1000m). For altitudes above 3,300 ft, de-rate the VF Drive by 1.2% for every 300 ft (100m).

3.14.1.9 Ratings

A. The VF Drive shall be designed to operate from an input voltage of 400 to 460 VAC ± 10% or 208 to 240 VAC ± 10%. Output voltage shall be 0 to maximum voltage, equal to input line voltage.

B. The VF Drive shall operate from an input voltage frequency range from 47.5 to 63 Hertz.

C. The displacement power factor shall not be less than .95 lagging under any speed or load condition.

D. The efficiency of the VF Drive shall not be less than 96% at 100% speed and load.

E. The overload current rating for variable torque (VT) shall be minimum 110%, for 1 minute; for constant torque (CT) shall be 150%, for 1 minute.

F. The output carrier frequency of the VF Drive shall be selectable at steps of 2kHz up to 10kHz for A frame; 8kHz for B frame; and 6kHz for C frame, depending on VF Drive rating for low noise operation. No VF Drive with an operable carrier frequency above 10 kHz shall be allowed. Or, the VF Drive shall have a switching frequency dependent on load in the 2 to 4 kHz range without a fixed carrier.

G. The output frequency shall be from 0.1 to 400 Hertz for VF Drives up to 75 HP. At horsepowers above 75 HP, the maximum output frequency will be 200 Hertz.

H. The VF Drive will be able to develop rated motor torque at 0.5 Hertz (60 Hz base), or at zero base, in a **Sensorless Flux Vector** mode using a standard induction motor without an encoder feedback signal.

I. For motor thermal protection function when the motor is operating at slow speed for extended times, the VF Drive shall have a protection function that detects motor overtemperature by wiring a motor thermistor (PTC) to a +24VDC voltage supply in the Drive. The VF Drive shall stop the motor and give a fault indication if the PTCs indicate motor overtemperature.

3.14.1.10 Protection

A. Upon power-up the VF Drive shall automatically test for valid operation of memory, option module, loss of analog reference input, loss of communication, [dynamic brake failure,] DC to DC power supply, control power and the pre-charge circuit.

B. The VF Drive shall be UL 508C listed for use on distribution systems with [10,000A RMS][22,000A RMS][65,000A RMS] available fault current. The Power Converter shall meet short circuit withstand ability of 65,000 RMS symmetrical amperes as defined by NEMA ICS 7.1.09 and have the value listed on the VF Drive nameplate.

C. The Power Converter shall be protected against short circuits, between output phases and ground; and between the logic and analog control outputs.

D. The VF drive shall have a minimum AC undervoltage power loss ride-through of 200 msec. The VF drive shall have the user defined option of frequency fold-back to allow motor torque production to continue to increase the duration of the powerloss ride-through.

E. The VF drive shall have a selectable ride through function which will allow the logic to maintain control for a minimum of one second without faulting.

F. For a fault condition other than a ground fault, short circuit or internal fault, an auto restart function will provide up to 5 programmable restart attempts. The programmable time delay before restart attempts will range from 1 second to 30 seconds, minimum.

G. The deceleration mode of the VF Drive shall be programmable for normal and fault conditions. The stop modes shall be free-wheel stop (coast to stop), DC injection brake, Ramp-to-Stop/Hold.

H. Upon loss of the analog process follower reference signal, the VF Drive shall be User programmable to do the following: Fault and stop; Alarm and maintain last reference (within 10%); Alarm and go to preset speed, which would be programmed to be minimum speed or maximum speed.

I. Motor overload protection: The VF Drive shall have solid state I2t protection that is UL listed and meets UL 508C as a Class 10 overload protection. The minimum adjustment range shall be from .45 to 1.05 percent of the current output of the VF Drive.

J. The VF Drive shall provide a motor phase loss function that monitors the status of the motor cable connection. During startup, if any of the motor phases are not connected the Drive shall refuse to start. The Drive shall have a user defined operation, during motor phase loss, of either a fault indication and stop, or no reaction.

K. The VF Drive shall have a thermal switch with a user selectable prealarm that will provide a minimum of 60 seconds delay before overtemperature fault. Or, the Drive shall provide access to the heatsink temperature parameter such that the user can monitor it.

L. The VF Drive shall be provided with cooling air fan(s) and/or may utilize bonded or cast fin heatsink construction for

maximum heat transfer. The cooling air must be clean and free from corrosive materials.

M. The VF Drive shall have a programmable fold-back function that will anticipate a controller overload condition and fold back the frequency to avoid a fault condition.

N. The output frequency shall be software enabled to fold back when the motor is overloaded. There shall be 3 skip frequency ranges that can each be programmed with a selectable bandwidth of 2 or 5 Hz. The skip frequencies shall be programmed independently, back to back or overlapping.

O. The VF Drive shall include phase to phase and phase to ground transient voltage surge protection wired to the incoming AC mains.

3.14.1.10 Factory Settings, Field Adjustments and Configurations

A. The VF Drive shall self-configure to the main operating supply voltage and frequency. No operator adjustments shall be required. The VF Drive shall be insensitive to incoming power phase sequence.

B. The VF Drive shall be capable of determining the speed and direction of a spinning motor and adjusting its output to engage the motor at the rotating speed.

C. Upon power-up, the VFD will automatically send a signal to the connected motor and store the resulting resistance data into memory. The inductance data will be measured during no-load operation when operating at a frequency between 20-60 Hz. The VFD will automatically optimize the operating characteristics according to the stored data.

D. The VF drive will be factory pre-set to operate most common applications.

E. A choice of three types of acceleration and deceleration ramps will be available in the AC Drive software; Linear, S curve, and U curve (or Linear, S1 curve, S2 curve, and S3 curve).

F. The acceleration and deceleration ramp times shall be adjustable from .1 to 999.9 seconds.

G. The volts per frequency (V/Hz) ratios shall be user selectable to meet variable torque loads, normal and high torque machine applications.

H. The Drive shall retain and record operating frequency, Drive status, power mode, and fault type of the past 4 faults, minimum. Information shall be maintained in memory in the event of a power loss.

I. Slip compensation shall be a software enabled function, if required.

J. The software shall have a No Load function that will reduce the voltage to the motor when selected for variable torque loads. A constant Volts/Hz ratio will be maintained during acceleration. The output voltage will then automatically adjust to meet the torque requirement of the load.

K. The AC drive shall offer programmable DC injection braking that will brake the AC motor by injecting DC current and creating a stationary magnetic pole in the stator. The level of current will be adjustable between 50-150% of rated current and available from 0.0-30 seconds continuously. For continuous operation after 30 seconds, the current shall be automatically reduced to 50% of the nameplate current of the motor.

L. Sequencing logic will coordinate the engage and release thresholds and time delays for the sequencing of the VFD output, mechanical actuation and DC injection braking in order to accomplish smooth starting and stopping of a mechanical process. Time delay can be an external option.

3.14.1.11 Operator Interface Terminal

A. The operator interface terminal will offer the modification of VFD adjustments via a touch keypad. All electrical values, configuration parameters, I/O assignments, application and activity function access, faults, local control, adjustment storage, self-test and diagnostics will be in plain English.

B. The display will be a high resolution, LCD backlighted screen capable of displaying operating parameters in percentages, and alphanumeric characters.

C. The VFD model number, torque type, software revision number, horsepower, output current, motor frequency and motor voltage shall all be listed on the drive identification display as viewed on the LCD display.

D. The display shall be configured to display numeric data that is selectable and scalable by the operator. A user defined label function shall be available. As a minimum the selectable outputs

shall consist of speed reference, output frequency, output current, motor torque, output power, output voltage, line voltage, DC voltage, motor thermal state, drive thermal state, elapsed time, motor speed, machine speed reference and machine speed.

E. A single keystroke scrolling function shall allow dynamic switching between display variables.

F. The terminal keypad will consist of predefined menus or programmable function keys. The functions will allow both predefined menus or operating commands and programming options to be preset by the operator. A hardware selector switch or programmed password will allow the terminal keypad to be locked out from unauthorized personnel.

G. The operator terminal will offer a general menu consisting of parameter setting, I/O map, fault history, and drive configuration. A software lock will limit access to the main menu. The main menu will consist of keypad configuration, drive configuration, general configuration, diagnostic mode and drive initialization screens.

H. There will be arrow keys that will provide the ability to scroll through menus and screens, select or activate functions or increase the value of a selected parameter.

I. A data entry key will allow the user to confirm a selected menu, numeric value or allow selection between multiple choices.

J. An escape key will allow a parameter to return the existing value if adjustment is not required and the value is displayed. The escape function will also return to a previous menu display.

K. A RUN key and a STOP key will command a normal starting and stopping as programmed when the VFD is in keypad control mode. Local STOP is not active in the remote control mode. Keypad will first have to be placed on local control mode for the VFD to be stopped locally.

L. The VFD shall come with 3 LEDs mounted on the front panel to indicate functional status. A Green LED will verify that the VFD power supply is ON. A Red LED indicator will indicate an VFD FAULT. A Yellow LED indicator will designate a PENDING FAULT condition.

M. A user interface shall be available that is a Windows 3.1 based personal computer, serial communication link or detachable

operator interface.

N. The Keypad and all door mounted controls shall be Type 1 [Type 12] rated.

O. All adjustments made on the user interface shall be stored in nonvolatile memory. The user interface shall provide memory for factory default values as well as programmed user defaults.

3.14.1.12 Control

A. External pilot devices shall be able to be connected to a terminal strip for starting/stopping the VFD, speed control and displaying operating status. All control inputs and outputs will be software assignable.

B. 2-wire or 3-wire control strategy shall be defined within the software. External relays or logic devices will not be allowed.

C. The control power for the digital inputs and outputs shall be 24vdc.

D. The internal power supply shall incorporate an automatic current fold-back that protects the internal power supply if incorrectly connected or shorted. The transistor logic outputs will be current limited and not be damaged if shorted or excess current is pulled.

E. All control logic connections shall be furnished on a terminal strip separate from power wiring.

F. There will be 2 software assignable analog inputs. The analog inputs will be software selectable and consist of the following configurations: 0-20 ma, 4-20 ma, 20-4 ma, x-20 ma (where x is user defined) 0-5 v, 1-5 v or 0-10 v. There will be 4 software assignable logic inputs that will be selected and assigned in the software. The selection of assignments shall consist of run/reverse, jog, plus/minus speed, setpoint memory, preset speeds, auto/manual control, controlled stop, terminal or keypad control, by-pass, motor switching, and fault reset.

G. There will be two software assignable analog outputs that can be selected and assigned in the software. The analog output assignments shall be proportional to the following motor characteristics: frequency, current, power torque, voltage and thermal state. The output signal will be selectable from 0-20 ma or 4-20 ma.

H. A minimum of two Form C relay output contacts will be provided. One of the contacts will indicate AC drive fault status. The other contact will be user assignable. There shall be a hardware input/output extension module which also provides interlocking and sequencing capabilities. The module shall be fully isolated and housed in a an enclosure with terminal strips. The module will add 4 logic inputs, 2 analog inputs, 2 relay outputs and one analog output. All of the I/O will be user assignable in the software as previously defined.

I. The VF Drive door mounted control area shall include a power ON, Drive RUN, Drive Fault Light and Hand-Off-Auto selector switch with Manual Speed Potentiometer.

J. The VFD control island shall accept [% indicating analog meters][obsolete indicating digital] meters to display [Power,] Amperes,][Voltage,][Hertz.]

[3.14.1.13 BRAKING (Application Dependent Option)

****
When braking certain types of loads, there is the conversion of kinematic energy into electrical energy by the motor which is returned to the VF Drive. Dynamic braking can be chosen to absorb this energy and avoid causing the VF Drive to inadvertently shut down. The energy is dissipated across a resistor that is connected to the Drive. For constant torque VF Drive controllers, the dynamic braking unit must be capable of stopping 1.5 per unit motor torque from base frequency to 0.5 Hz with sensorless flux vector control mode.
****

A. A dynamic brake resistor shall be provided and connected to existing terminals on the VF Drive. The resistor shall mount externally to the VF Drive enclosure. An IGBT will be provided in the Drive to switch excess regenerative energy to the braking resistor. The braking resistor will be of a size calculated to stop 6 times motor inertia at 1.5 per unit motor torque.

B. Provisions shall be provided to protect the Dynamic Braking Resistor against overload and overcurrent due to Dynamic Brake switch failure. This protection must be resetable without replacement of fuses or other devices.]

3.14.1.14 Isolation/Bypass Contactors (Automatic)

The VFD shall include an isolation and bypass contactors complete

with thermal overload relay, circuit breaker disconnect interlocked with the door, control circuit transformer, motor flux decay timer and VFD-OFF-BYPASS selector switch. The operator may select for manual bypass by setting the switch in the BYPASS position or automatic bypass by setting the switch in the VFD position. In the VFD position the VF Drive will provide variable frequency/speed control of the motor under non-fault conditions of the Drive. When the Drive is under a fault condition the bypass contactor will be automatically energized upon Drive shutdown (Drive fault contact operation) to operate the motor, across the line, on 60 Hertz line power and on a full voltage non-reversing starter with overload relay.

3.14.1.15 Harmonic Current Filtering

****
The distortion factor must not exceed 3 percent for individual phases and 5 percent for the power system used to supply the VFDs and other loads. A study will be required if the combination of harmonics on the power system and those generated by the VF Drives could produce unacceptable aberrations on the power system. Provide either an isolation transformer of adequate size or reactors of minimum 3% per unit impedance, on the primary of the VF Drive to act as a buffer and reduce the current harmonics that are fed back into the electrical supply power system. Further designer directions for harmonic analysis can be found in TM 5-811-13 "Standards and High-Efficiency Motors and Controllers" Chapter 2, para. 2-6(d); for direction on PFC Capacitor Application on motors with VF Drives, refer to para. 4-7(4). Capacitors will not be installed on the motor side of the VF Drive.
****

[A. A harmonic analysis shall be performed by the VF Drive manufacturer base upon system documentation consisting of but not limited to one-line diagrams and specific distribution transformer information consisting of KVA, %Z, and X/R data. The analysis data shall consist of but not be limited to total harmonic voltage distortion and total current.]

B. [Line reactors][an isolation transformer] shall be provided in a stand-alone NEMA enclosure for mounting separately from the VF Drive. [Line reactors shall be of minimum 3% per unit impedance, and may be provided integral to the VF Drive. All line reactors, integral or external type, shall be provided by the VF Drive manufacturer as a part of the VFD package.]

[C. The isolation transformer shall be of adequate size with

full capacity taps 4-2.5% 2+ 2-, to provide voltage change if necessary to match the motor drive voltage requirements. The isolation transformer shall provide an isolated secondary winding which shall be grounded to a separate isolated building ground point, in order to insure that AC Drive "noise" is not coupled back into the Line side of the service primary system and affects other equipment connected on the Line side. The isolation transformer shall provide reactive buffer to ease the rate of current change in the solid state switching elements contained in the VF Drive. The windings shall allow for additional heating as a result of eddy current loss in the transformer windings carrying harmonic currents. Core design shall feature reduced flux density to prevent core saturation effects as a result of voltage waveform distortion caused by harmonic currents.]

3.14.1.16 Execution

A. The contractor shall not install the VF Drive(s) until the building environment can be maintained within the service conditions required by the manufacturer. Before and during the installation, the VF Drive equipment shall be protected from site contaminants. Installation shall be in compliance with manufacturer's instructions, drawings and recommendations.

B. The Contractor shall provide a manufacturer's certified technical representative to supervise the contractor's installation, testing and start-up of the VF drive(s) furnished under this specification for the minimum number of days required for the technical representative to approve the installation and operation of the AC Drive. In addition, the manufacturer’s technical representative shall provide training to the User's personnel.

C. Six months after start-up, the contractor shall provide a manufacturer’s certified technical representative to make a one-day site visit to inspect the VF Drive(s) and accessories.

3.14.1.17 Training

An on-site training course of 3 training days shall be provided by a certified representative of the VF Drive manufacturer to the User's plant and/or maintenance personnel. The training course shall include VF Drive model brochures, and troubleshooting manuals that describe accurate procedures to follow for maintenance personnel to quickly isolate a cause for Drive failure.